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PERFORMANCE EFFECTIVENESS AND EFFICIENCY UNDER DIFFERENT DYADIC WORK STRATEGIES

(Interim Report)

by

CPT Samuel C. Shiflett, MSC (Ph.D.)

23 December 1971

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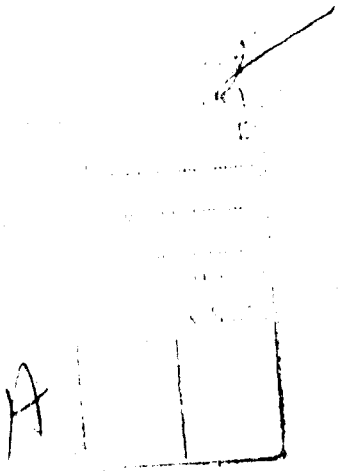

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The effects of three task solving strategies upon group efficiency and effectiveness were studied. Sixty soldiers worked in dyads under a shared labor strategy or one of two divided labor strategies. Tasks were a difficult and an easy crossword puzzle. On the average, dividing labor resulted in greater efficiency (amount of work per man-hour) while requiring Ss to work together resulted in substantially greater group effectiveness (total performance), but this effect occurred primarily on the easy task. It was suggested that a high degree of member interdependence maximizes redundancy of task-relevant abilities, resulting in generally superior performance effectiveness but frequently at the cost of efficiency.

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ABSTRACT

PERFORMANCE EFFECTIVENESS AND EFFICIENCY UNDER DIFFERENT DYADIC WORK STRATEGIES

OBJECTIVE

To determine the effects of maximal and minimal member interdependence and redundancy of task-related ability on efficiency and effectiveness of dyadic group performance.

METHOD

Sixty soldiers worked in dyads under a shared labor strategy or one of two divided labor strategies on two crossword puzzles, one relatively easy, one relatively difficult.

SUMMARY

On the average, dividing labor resulted in greater efficiency (amount of work per man-hour), while requiring subjects to work together resulted in substantially greater group effectiveness (total performance). Shared labor resulted in greater effectiveness on the easy task but not on the difficult task.

CONCLUSION

High member interdependence maximizes redundancy of task-relevant abilities, resulting in superior performance. Dividing labor minimizes redundancy thereby increasing average efficiency but reducing average effectiveness. The interaction between strategy and task difficulty suggests that the concept of task difficulty needs to be more clearly defined.

PERFORMANCE EFFECTIVENESS AND EFFICIENCY UNDER DIFFERENT DYADIC WORK STRATEGIES

INTRODUCTION

It has been argued that groups can potentially increase performance through redundancy of ability (1,2). That is, if a task requires all group members to work together and if individual performance is such that some probability of failure to perform adequately exists, then redundancy of ability or task relevant knowledge increases the probability that the task will be performed adequately. Furthermore, as a task becomes more difficult the probability of performance failure presumably increases, and so in order to maintain adequate group performance, the necessity for redundancy also increases. On a very easy task the necessity for redundancy disappears since the probability of an individual failing, or making an error, approaches zero.

The amount of redundancy in a group can be manipulated in several ways, as suggested by Goldman (3), Laughlin, Branch and Johnson (4), and Steiner (5). Shiflett (6) attempted to manipulate redundancy by varying member interdependence. He found that variations in dyadic organizational structures resulted in different levels of performance efficiency and effectiveness. The term "efficiency" refers to group productivity in terms of man-hours (7) while "effectiveness" refers to maximum group performance, without regard to time. This distinction is similar to the distinction made between speed and power in ability testing. Shiflett (6) found that a shared labor organization, where both members were required to work together, and therefore a high redundancy situation, resulted in greater effectiveness but somewhat less efficiency than a divided labor strategy, where redundancy was effectively nil, on both an easy and a difficult task. These findings were in contrast to the hypotheses that divided labor would be equally effective on an easy task, as well as more efficient, and that shared labor would be more efficient and more effective when the task was difficult. Failure to fully support these hypotheses was attributed to the particular manner in which the labor was divided. Divided labor groups solved crossword puzzles in which one member had only vertical definitions, the other had only horizontal definitions, and the two members were not permitted to discuss their definitions with each other. This particular division of labor introduced communications and feedback difficulties by introducing relatively high task interdependence with low content related communicability. If one member made an error it became more difficult for the other member to fill in his adjoining words and the restriction on communication made it difficult for members to locate the error. This was particularly true since each member had no way of determining whether he had made an error on the basis of his own performance; he could do this only through vague communication with his partner. A more appropriate labor division which would eliminate these problems would be to allow each member to work on one intact half of each puzzle.

The purpose of this study was to replicate portions of the Shiflett (6) study incorporating the appropriate modifications mentioned above. It was expected that on an easy task, the modified divided labor strategy would be more efficient than the shared labor strategy because of the reduced redundancy, and that it would be equally effective because redundancy was not necessary. On a more difficult task the shared labor strategy was expected to be more effective and more efficient than the modified divided labor strategy because of the necessity for increased redundancy. The modified division of labor was expected to be superior to the original vertical-horizontal division of labor in both efficiency and effectiveness.

METHOD

Subjects. Subjects were 60 soldiers who had just completed basic training. The men were assigned to the research laboratory for 6-week periods in groups ranging from 16 to 20 men. The experiment was conducted during the second or third week of their duty at the laboratory, and the men within each group were acquainted with one another prior to participation in this experiment. The men ranged in age from 18 to 24, and in education from less than a high school diploma to college graduate. Although men scoring below 100 on the Army GT test were never assigned to the laboratory, the mean puzzle-solving ability of the soldiers, as assessed by the pre-test described by Shiflett (6), was more than one standard deviation below the ability of the college population used in the 1972 study.

Task. Two crossword puzzles, one relatively difficult and one relatively easy, were cast in a symmetrical "skeleton" design in which each word had either one or two letters which were not shared with any other word. Each puzzle contained 48 four-letter words. No words were repeated within or across puzzles. While subjects worked on the puzzles, the experimenter observed them with a scoring sheet containing a copy of the puzzle outline. Whenever a word was written into the puzzle, the experimenter entered the time into the corresponding location of his own puzzle outline. Groups worked on each puzzle for 20 min. The number of correct words filled in during each 2-min block was then tabulated, yielding word frequencies for each of the 10 blocks during the 20 min. Half of the dyads worked the easy puzzle first, and half worked the difficult puzzle first. At the end of each session subjects filled out a short questionnaire consisting of a series of bipolar scales assessing activity and satisfaction.

Procedure. Subjects were randomly paired and assigned to one of three organizational strategy conditions. Subjects always worked on both puzzles using the same labor strategy. The first two conditions described below were identical to their counterparts described by Shiflett (6). The third condition was the modified divided labor strategy.

Shared Labor Strategy. Subjects were given a single puzzle outline and a single set of definitions. They were told that they must work

together on each word in the puzzle and both agree on a word before writing it down.

Vertical-Horizontal Division of Labor Strategy. The experimenter placed a single puzzle outline between the subjects and explained that one of them would work only the horizontal words and the other only the vertical words. Each subject then received his set of definitions. Subjects were allowed to converse as much as they wished, but they could not indicate to each other what was printed on their own definition sheet.

Diagonal Division of Labor Strategy. This condition was identical to the vertical-horizontal division with the following exception. The puzzle outline had a line drawn diagonally through the puzzle, dividing the outline into two equal parts. The experimenter placed the puzzle outline between the subjects and explained that one of them would work only the words in the area above the diagonal and the other only the words below the diagonal. Each subject then received the appropriate set of definitions. They were allowed to talk to each other but could not discuss the definitions.

RESULTS

The number of words completed per 2-min period was calculated for each group, and constituted the measure of group performance. These data were submitted to a 4-way analysis of variance with repeated measures on two factors. The summary of this analysis is presented in Table 1. Effects of Time, Difficulty, and Strategy were significant, as were all three 2-way interactions involving these factors. On the average, more words were correctly completed on the easy puzzle per 2-min block than on the difficult puzzle (3.27 vs. 2.26). The mean number of words per 2-min block declined significantly from a high of 6.31 during the first 2 min to 1.06 words during the last 2 min, suggesting that the tasks became more difficult as work progressed. Shared labor produced the highest level of performance with an average of 3.27 words per block; vertical-horizontal division of labor produced the lowest level of performance with an average of 2.25 words per block; the diagonal division of labor was intermediate in performance with 2.79 words per block. The Studentized range statistic indicated that each of these three means was significantly different from the others at the .01 level. This result thus substantiated the hypothesis that dividing labor vertically and horizontally produced poorer group effectiveness than a diagonal division. However, contrary to the prediction that the shared labor and diagonal division of labor would be equally effective was the finding that shared labor was significantly more effective than either of the divided labor strategies.

The Time by Difficulty interaction indicated that performance on the easy puzzle was significantly greater than on the difficult puzzle during the first 6 min but not during the subsequent 14 min. The Strategy by Difficulty interaction indicated that on the easy task, shared labor performance was significantly greater than performance under either of the

TABLE 1

SUMMARY OF ANALYSIS OF VARIANCE OF PERFORMANCE

Source	df	MS	F
Between Subjects			
Order (O)	1	5.23	< 1
Strategy (S)	2	52.08	5.190*
O x S	2	1.31	< 1
Error (Between)	24	10.04	
Within Subjects			
Time (T)	9	204.01	47.292***
T x O	9	2.14	< 1
T x S	18	20.53	4.759***
T x O x S	18	4.43	1.028
Error (T x Ss Within)	216	4.31	
Difficulty (D)	1	154.03	177.591***
D x O	1	1.13	1.299
D x S	2	5.89	6.787**
D x O x S	2	1.73	1.990
Error (D x Ss Within)	24	.87	
T x D	9	8.29	2.548**
T x D x O	9	2.19	< 1
T x D x S	18	3.06	< 1
T x D x O x S	18	1.75	< 1
Error (TD x Ss Within)	216	3.25	

*p < .05
**p < .01
***p < .001

divided labor strategies, whereas on the difficult task, shared labor performance and diagonal division of labor both exceeded vertical-horizontal division of labor, but did not differ from each other. In other words, the shared labor strategy resulted in greater effectiveness than divided labor on the easy task but not on the difficult task, thereby contradicting the basic hypothesis regarding the interaction between strategy and task difficulty.

The Strategy by Time interaction, shown in Figure 1, indicated that during the first 6 min, diagonal division of labor yielded better performance than shared or vertical-horizontal division of labor, while after 8 min, shared labor performance exceeded that of both divided labor conditions. The vertical-horizontal divided labor performance generally paralleled shared labor performance during the first 6 min but closely paralleled diagonal division performance from minute 8 to 20.

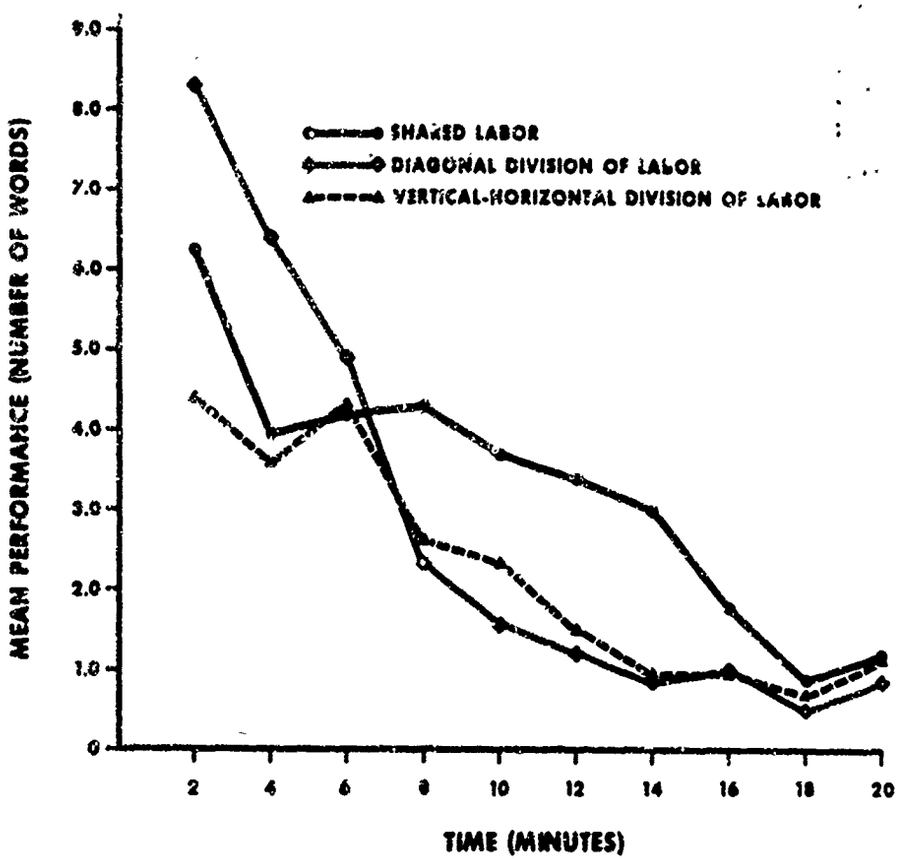

Fig. 1. Mean group performance across time for three different labor strategies.

The significant differences between shared labor and diagonal division of labor and the change in the sign of the mean differences constitute support for the hypothesis that division of labor is more efficient but, given enough time, shared labor could equal that performance. In fact, shared labor performance significantly exceeded that of divided labor during the last half of the session. This effect is more clearly shown in terms of "efficiency" in Figure 2, where the performance scores are

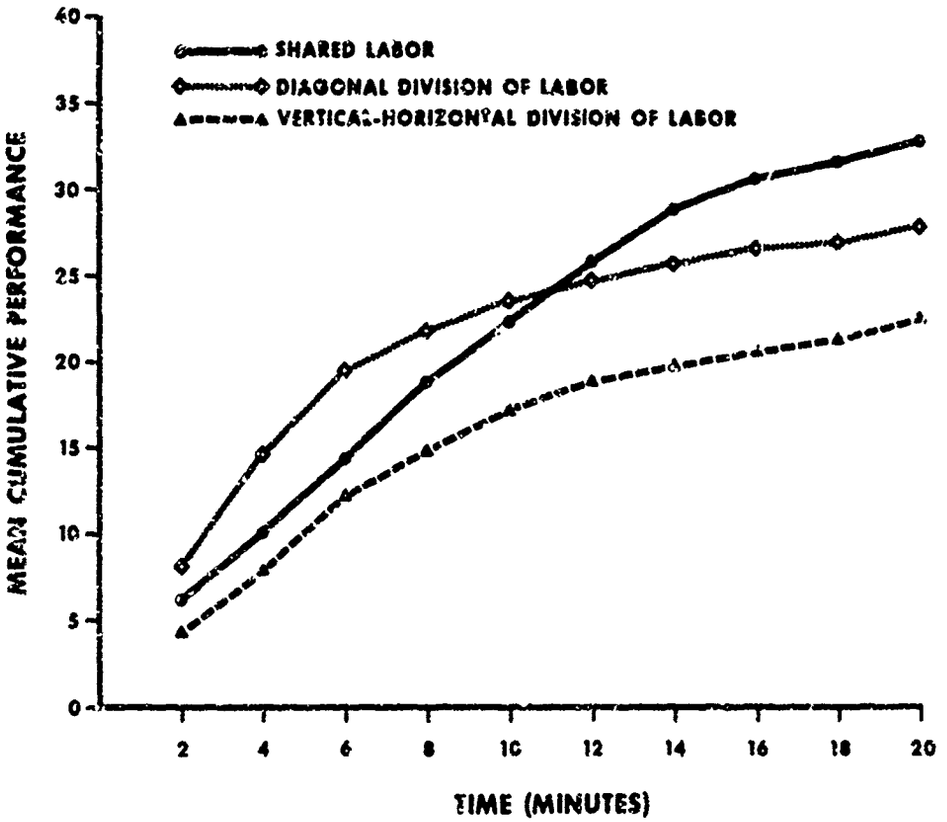

Fig. 2. Cumulative group performance for each labor strategy.

cumulated over time. The diagonal division was clearly more efficient during the first half of the experimental session while the shared labor condition was more effective during the last half. The depressed vertical-horizontal divided labor curve suggests that this type of labor division created a much more difficult situation for the subjects.

Time-to-criterion scores were obtained to test the hypothesis that when performance effectiveness was equated, divided labor would be more efficient than shared labor. Performance on the difficult task was at such a low level that an analysis of time data for this task was not attempted. On the easy task a criterion of 25 words* was used, requiring that two groups from each of the three strategy conditions be dropped from the analysis. In addition, times to sub-criteria (5, 10, 15 and 20 words)

*As contrasted with a similar criterion of 45 words for the same type of analysis used in the previous study involving college students (6).

were obtained and an analysis of variance containing two factors, Strategies and Criteria, was performed on the time scores. The summary of this analysis is presented in Table 2. Diagonal division of labor was the most efficient organization requiring 6.75 min to reach criterion while vertical-horizontal division of labor was least efficient using 11.35 min to reach criterion. Shared labor was intermediate in efficiency, requiring 9.35 min to reach criterion. The extent to which vertical-horizontal division of labor increased inefficiency is thus clearly demonstrated. In addition, the added efficiency of the diagonal division of labor is apparent; however, a Newman-Keuls test indicated that the difference between diagonal division and shared labor means did not reach significance at the .05 level. The significant Criteria effect reflected a general increase in the amount of time to fill in five words as the 25-word criterion was approached. The significant interaction between Criteria and Strategies indicates that this effect is true for the divided labor strategies but not for the shared labor strategy which maintained a much more consistent pattern of performance across criteria.

TABLE 2

SUMMARY OF ANALYSIS OF VARIANCE OF TIME-TO-CRITERION SCORES

	df	MS	F
Strategy (S)	2	24.01	7.80**
Error (Between)	21	3.08	
Criteria (C)	4	6.03	3.03*
S x C	8	4.22	2.12*
Error (Within)	56	1.99	

*$p < .05$
**$p < .01$

The questionnaire items were combined to form "activity level", "interpersonal relations" and "task satisfaction" scores in a simple summation procedure described previously by Shiflett (6). The analysis of variance of the activity level scores indicated that diagonal division of labor produced significantly lower activity ratings than did either the vertical-horizontal labor division or the shared labor condition ($F = 13.054$, $df = 2/24$, $p < .001$). Vertical-horizontal labor division and shared labor produced virtually identical activity level ratings of

227.05 and 227.85 (vs. 186.40 for diagonal labor division). The substantial difference in task performance for these two conditions, coupled with their similar activity levels confirms the hypothesized deleterious effects of high task interdependence and low communicability.

The different labor strategies also significantly affected reported interpersonal relations ($F = 13.453$, $df = 2/24$, $p < .001$), with shared labor producing the most positive ratings and diagonal division of labor producing the least positive ratings. This latter result, occurring among previously acquainted subjects, probably reflects the fact that there was very little interaction of any kind in the diagonal division of labor as a result of experimentally manipulated restrictions on communication. The analysis of variance of task satisfaction ratings produced no significant F-ratios.

DISCUSSION

The results have clearly demonstrated the superiority of the diagonal division of labor over the horizontal-vertical division with respect to both efficiency and effectiveness. The contention that the latter division introduced problems of high task interdependence with low communicability thus appears to be supported. These results also suggest that definite feedback regarding performance may substantially improve both efficiency and effectiveness. The same basic pattern of results reported by Shiflett (6) was obtained for the shared labor and diagonal division of labor: the divided labor strategy was generally more efficient while the shared labor strategy was more effective. The hypothesis that divided labor would be equally effective on an easy task was not supported since shared labor was more effective on both the easy and difficult tasks.

The superiority of the shared labor strategy may lie in the redundancy of the abilities of the two members which increased the probability that at least one member will have the correct solution, as suggested by Zajonc and Smoke (2). However, on the more difficult task, the shared labor strategy, in which redundancy is maximized, failed to yield performance which significantly exceeded divided labor performance, where redundancy is effectively nil. This fact argues against the Zajonc and Smoke hypothesis and suggests that there may be a curvilinear relationship in which at the very easy and very difficult extremes redundancy is of little value, while at the intermediate levels redundancy is a major factor in increasing performance. At the easy extreme, overlapping ability is maximal but anyone working alone can do the same job as several persons working together while at the difficult extreme what is becoming highly redundant is not ability but the lack of it.

As shown in Figure 2, the vertical-horizontal division of labor performance curve never exceeds the shared labor or diagonal division of labor curve. In the original study, vertical-horizontal division of labor did exceed shared labor performance during the first few minutes and occupied an almost identical relationship relative to shared labor as does

the present diagonal division of labor performance. It thus seems likely that had the diagonal division of labor been used in the original study, where average ability was much higher, the hypothesis regarding efficiency of dividing labor would have been even more clearly supported.

Inspection of Figure 1 indicates that, in terms of mean performance, the puzzles strongly differ in difficulty only during the first 6 to 8 min. After that time the difference in difficulty is small and non-significant. This same finding occurred in the original study, but the strong ceiling effect on performance which occurred there obscured this fact. Little, if any, ceiling effect operated in the present study, due primarily to the much lower ability level of the subjects (only two groups completed the easy puzzle). In general, there was little difference in difficulty between the two puzzles, as defined by word frequency, during the latter two-thirds of the experimental period. The initially large differences in performance caused the tasks to remain significantly different in performance and, therefore, in perception of difficulty.

An additional problem with the definition of difficulty exists in the decline in performance over time which occurred on both the easy and the difficult task. This effect also occurred in the Shiflett (6) study, but was obscured by the fact that performance rapidly reached a maximal or near maximal level on the easy task due to the fact that so many groups nearly finished the task within 10 min. In the present study, performance again approached an asymptote, but the much lower level of performance here suggests that the ceiling effect is a reflection of lower ability levels rather than a task-imposed limitation. The substantially lower performance levels of the present groups, as compared with the previous groups, are consistent with the differences in pre-test ability levels and suggests that both tasks were, on the average, more difficult for the present subjects than for the original subjects. To the extent that performance level reflects task difficulty it can be argued that the difficulty of the task (filling in the remaining words) increases as the work proceeds. This effect probably reflects a tendency for subjects to fill in the easier words first and progress to the more difficult words within a puzzle.

A final and more general problem exists in the definition of task difficulty. The crossword puzzles were defined as if the property of task difficulty existed independently of the ability level of the individuals working on the puzzle. This is probably adequate in an ordinal sense since the difficult puzzle is relatively more difficult than the easy puzzle for almost all of the subjects used in these two studies, in terms of both performance and rating of difficulty. However, difficulty is also closely related to the relevant ability of the individual working on the task. Thus a task may be seen as difficult or even impossible to a person with little task-relevant ability but be seen as rather easy to a person with high ability. This same difference in perception can be expected to be reflected in actual task performance. Task difficulty, then, is relative to individual ability. Task difficulty can be defined relative

to other tasks and relative to the ability of the persons performing the task. It has also been demonstrated that task difficulty may change in the course of working on the task. The failure to find that redundancy substantially aided group performance in the difficult task but instead was more helpful on the easier task was perhaps the most surprising result of this study. In light of this finding, efforts to understand just how group organization and the distribution of resources within a group affect group performance and process may have to consider more carefully the effect of the interaction between task difficulty and member ability on those dependent variables.

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